

Stellar Membership and Dusty Debris Disks in the α Persei Cluster

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Abstract. Because of proximity to the Galactic plane, reliable identification of members of the α Persei cluster is often problematic. Based primarily on membership evaluations contained in six published papers, we constructed a mostly complete list of high-fidelity members of spectral type G and earlier that lie within 3 arc degrees of the cluster center. α Persei was the one nearby, rich, young open cluster not surveyed with the Spitzer Space Telescope. We examined the first and final data releases of the Wide Field Infrared Survey Explorer (WISE) and found 11, or perhaps 12, α Per cluster members that have excess mid-infrared emission above the stellar photosphere attributable to an orbiting dusty debris disk. The most unusual of these is V488 Per, a K-type star with an excess IR luminosity 16% (or more) of the stellar luminosity; this is a larger excess fraction than that of any other known dusty main sequence star. Much of the dust that orbits V488 Per is at a temperature of ~ 800 K; if these grains radiate like blackbodies, then they lie only ~ 0.06 AU from the star. The dust is probably the aftermath of a collision of two planetary embryos or planets with small semimajor axes; such orbital radii are similar to those of many of the transiting planets discovered by the Kepler satellite.

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1. INTRODUCTION

Unveiling the evolution of dusty debris disks as a function of stellar age was a major focus of studies of main sequence stars with the Spitzer Space Telescope. Rebull et al (2008) and Gaspar et al (2009) each presented tables listing stellar associations and clusters of known age and the fraction of these stars with Spitzer-detected excess infrared emission. In a recent paper, we added the AB Doradus, Tucana/Horologium, and Argus associations to such tabulations (Zuckerman et al 2011, Table 11).

The α Persei cluster (hereafter α Per) is the only nearby (182 ± 11 pc, Jackson & Jefferies 2010; 191 ± 7 pc, Robinchon et al. 1999; 183 pc, Makarov 2006), rich (hundreds of members), open cluster not surveyed by Spitzer; indeed, at an age of ~ 60 Myr (Section 3.2) it is the youngest rich open cluster in the solar vicinity. To partially rectify this omission we correlated mid-infrared sources in the first and final WISE data releases with members of α Per that have spectral classes between M- and B-type, but with most emphasis on G-type and earlier. Because one of our goals was determination of the fraction of cluster members with WISE-detected mid-IR emission above the stellar photosphere, it was important to identify stars with a high probability of membership. Toward this end, we evaluated results from various published papers to compose lists of likely and possible cluster members (Tables 1 and 2, respectively). The list in Table 1 should be mostly complete for stars of spectral type G and earlier and located within 3 degrees of the α Persei cluster center which we took to be $03^{\text{h}}26.0^{\text{m}}+49^{\text{d}}07'$ (Kharchenko et al 2005).

In the following sections we outline our search procedure for dusty α Per stars, discuss a few of the dusty stars that appear in Table 3, and consider where α Per stands relative to other young open clusters and associations as regards the presence of dusty debris disks. In compiling Tables 1 and 2 we had occasion to consult many of the important papers written about the α Persei cluster. These and additional important papers are cited in Section 3.2 where we consider the relative ages of α Persei and other nearby stellar clusters and associations.

2. SEARCH PROCEDURE FOR EXCESS INFRARED EMISSION

Our identification of α Per members with dusty debris disks involved three principal steps. First we produced a list of likely cluster members. We correlated this list with the WISE catalog, and then searched for stars with infrared emission above the stellar photosphere.

2.1. α Persei Input Samples

To maintain as wide a breadth as possible in the early stages of our search, we employed three cluster input catalogs. The first was taken from the WEBDA online service (<http://www.univie.ac.at/webda/>), another was from Makarov (2006), and the third was generated by ourselves from a focused search of the UCAC3 catalog (Zacharias et

al 2009). All sources listed in the WEBDA α Persei catalog (regardless of membership probability) were searched for infrared excess emission (see Section 2.2), as were all 139 stars listed in Table 1 of Makarov (2006) and identified by him as "high fidelity" members. Because Makarov's list is mostly complete only to spectral type mid-G and earlier, our search of the UCAC3 catalog was designed to reveal late-type stars with exceptionally large mid-IR excess emission similar to and in addition to that of V488 Per (Section 3.1, Figure 2), but none were found.

The UCAC3 input sample was generated as follows. We searched the UCAC3 catalog within 3 arc degrees of the α Persei cluster center at 03h26.0m +49d07'. To restrict the size of the search output, we further required that a star have proper motion errors of less than 10 mas/yr in each of RA and DEC, that pmRA lie between 7 and 37 mas/yr, and that pmDEC lie between -40 and -10 mas/yr. The proper motion of stars meeting these criteria were compared to the mean α Persei proper motion values (pmRA=21.98 \pm 0.20 mas/yr, pmDEC=-25.36 \pm 0.17 mas/yr; Kharchenko et al. 2005). If the UCAC3 proper motions of a queried source agreed with the mean cluster proper motion values to within 3-sigma of their respective uncertainties, then the source was tentatively labeled as a cluster member. All tentative cluster members were then searched for infrared excess emission.

The WEBDA service collects data products from papers that discuss open clusters. The service makes no effort to vet these data products, and merely adds them as-is to their repository. This means that if, for example, a paper were to report imaging photometry of sources in the field around α Persei, all such sources would be added to the WEBDA α Persei cluster database regardless of actual membership status. In this way the WEBDA service collected >3000 candidate α Persei cluster members. To be as conservative as possible, and to enable as much infrared discovery as possible, we started with all 3000+ candidates given by WEBDA for the α Persei cluster. These candidates come from 14 sources, three of which are cited in the present paper in other contexts.

To compile excess statistics, cluster members both with and without infrared excess emission needed to be culled from our larger input catalogs. Proper motion information, photometric distance estimates, and radial velocity measurements (when available) were used to identify members and to remove non-members from our input samples. In this way the majority of the WEBDA input sample was rejected.

Following our own search, as outlined in the preceding four paragraphs, we then turned to the α Persei cluster literature. In addition to Makarov (2006), we principally utilized six other papers (Tables 1 and 2, see the six right hand columns and the table notes) to identify likely and possible cluster members. In addition to proper motion, Hipparcos and photometric distances, and radial velocities, lithium abundance and X-ray fluxes have been utilized to establish cluster membership in these various papers.

Makarov's (2006) selection criteria are described in the first two sentences of his abstract: "A kinematical study of the nearby open cluster α Persei is presented based on astrometric proper motions and positions in the Tycho-2 catalog and Second USNO

CCD Astrographic Catalog (UCAC2). Using the astrometric data and photometry from the Tycho-2 and ground-based catalogs, 139 probable members of the cluster are selected, 18 of them new.”

As noted two paragraphs previous, we and others have used criteria in addition to those employed by Makarov. The result is that 117 of Makarov’s 139 suggested members appear in our Table 1 and 20 appear in our Table 2. As may be seen by inspection of Table 2, the principal reasons why 20 stars from Makarov’s list are deemed by us to be only possible cluster members is because either other authors do not agree with Makarov or because no data other than kinematics and photometry are available. By contrast, almost all stars listed in Table 1 are regarded as members in at least two papers. In the few cases where an ”n” (nonmember) or ”n?” appears in Table 1, such characterization is often superceded in later references, sometimes by the same authors.

While Table 1 should be a mostly complete list of members of spectral type G and earlier and located within 3 degrees of the cluster center, the table only sparsely samples later-type members (e.g., AP members listed by Prosser 1992). Because of WISE sensitivity limits that would require huge fractional excess IR emission for cluster members later than spectral type G, we have not made an effort to identify such stars. Therefore, many previously suggested late-type cluster members do not appear in Tables 1 and 2. Also, although we considered X-ray data when compiling Tables 1 and 2 (e.g. Randich et al 1996), we did not do a thorough search of all published X-ray papers that might be relevant to identification of cluster members.

2.2. WISE Cross-correlation

Each input catalog of α Persei stars was initially cross-correlated with the preliminary (2011) WISE catalog. Given the WISE angular resolution of 6.1”, 6.4”, 6.5” and 12.0” in its four bands of 3.35, 4.60, 11.56, and 22.09 μm (Wright et al 2010), we used a search radius of 10” to identify WISE counterparts of input catalog stars. For conversion from WISE magnitudes to the flux densities given in Table 3 we used 0 (Vega-magnitude) flux densities of 306.68, 170.66, 29.045, and 8.284 Jy and color corrected these as appropriate for each star.

Spectral energy distributions (SEDs) for each matched source were generated using 2MASS photometry, WISE data, and any other available photometry (e.g., Tycho-2 BV magnitudes). A fully automated SED-fitting technique employing a theoretical atmospheric model (Hauschildt et al 1999) was used to predict stellar photospheric fluxes. A detailed description of our photospheric fitting procedure is given in Section 2 of Rhee et al (2007), so we do not repeat it here. In Section 3 of our recent paper (Zuckerman et al 2011) we describe how we checked this theoretical model against actual MIPS measurements of stars that show no evidence for an infrared excess. The result was an upward correction of the model photospheric flux densities at 24 μm by a factor of 1.03. Therefore, in Table 3 the listed 22 μm photospheric flux densities are those produced from the theoretical model, multiplied by a factor of 1.03.

From a sample of 149 likely cluster members (Table 1), mostly B-, A-, F- and G-type stars, in the 2011 WISE catalog we initially identified a total of 11 α Per cluster members with excess mid-IR emission, probably due to orbiting dust particles (Table 3; Figures 1-2). The final (2012) version of the WISE catalog appeared shortly before this paper was finalized and the same 11 stars were identified; all Table 3 flux densities are from the final WISE catalog. These 11 include V488 Per which is the only star with excess emission in each of the four WISE filters (see discussion of V488 Per in Section 3.1). For each of the 11 stars in Table 3, the 22 μm excess is at least 5 times the listed WISE uncertainty. In addition to these 11 stars, HD 21855 might have a 22 μm excess (see discussion in Section 3.1).

2.3. Spitzer/IRAC Observations of V 488 Per

V488 Per was serendipitously observed with the Infrared Array Camera (IRAC; Fazio et al. 2004) on Spitzer through a program searching for substellar companions to low mass stars in α Per (AORKEY: 18853632). It was observed in all four IRAC channels on 9-26-2006. IRAC Post Basic Calibrated Data (pBCD) mosaic files were obtained from the Spitzer Heritage Archive. Source extraction was performed on the pBCD mosaics utilizing the Astronomical Point Source Extraction (APEX) package, and the IRAC data points are added to the SED of V488 Per to further constrain the dust fitting (Figure 2). The Spitzer IRAC observations support the large L_{IR}/L^* indicated by WISE for this object.

3. DISCUSSION

We identified 11 stars with excess emission above the stellar photosphere at 22 μm and sometimes at other wavelengths (Table 3, Figures 1 and 2) that can definitely or probably be attributed to an orbiting dusty debris disk. While most are of early-type – for which the detected dust emission is usually the Wien tail of emission at longer wavelengths generated by cool dust particles – one remarkable K-type star, V488 Per, appears in Tables 1 and 3 and Figure 2.

The distribution of spectral types in Table 3 is five B, three A, two F and one K. Some additional B-type stars display excess emission as measured by WISE, but these excesses are more likely due to free-free radiation in an outflowing ionized stellar wind rather than from an orbiting debris disk. Characteristically, when emission is due to free-free transitions, then IR flux densities decline toward longer wavelengths. One prominent Table 1 example of such a star is ψ Per, strongly detected with IRAS many years ago. Another such B-type star is HR 1037 (= HD 21362; compare the 24 and 70 μm MIPS measurements reported by Su et al (2006) with the WISE catalog flux densities).

Below we consider a few stars in Table 3 and also the stars 29 Per and HD 21855. These are followed by a discussion of the evolution of dusty debris disks.

3.1. Individual SEDs

29 Per: This B3 star, whose SED is shown in Figure 1, might be expected to display an outflowing ionized wind as mentioned just above. However, the shape of the SED of 29 Per is very different from that of other B-type stars. The excess emission at 22 μm is weak, whereas IRAS measured strong excess emission at 60 μm (Figure 1). We therefore inspected the WISE 22 μm images and also used the IRAS "scanpi" function to characterize the spatial distribution of the 60 μm emission in the vicinity of 29 Per. The WISE image displayed in Figure 3 illustrates the extended nature of the 22 μm emission. Our conclusion is that the excess emission is carried by heated interstellar dust ("cirrus") at substantial distances from 29 Per and not to an orbiting debris disk. Thus, 29 Per is included in Figure 1 to illustrate its SED, but not to suggest the presence of a debris disk.

V488 Per: This solar-type star has a larger fractional infrared luminosity, defined as the ratio of excess infrared luminosity to bolometric luminosity (τ), than any other known main sequence star. From the SED in Figure 2, $\tau \sim 16\%$, to be compared to the previous main sequence champion BD+20 307 with $\tau \sim 3.3\%$. (Song et al 2005; Weinberger et al 2011). Most main sequence stars with strong mid-IR emission from warm dust particles show no evidence for substantial quantities of cool dust (e.g.. Melis et al 2010; Melis et al 2012; Weinberger et al 2011; and references therein). However, as may be seen from blackbody fits to its SED, substantial quantities of both warm and cool dust particles orbit V488 Per.

Much of the dust that orbits V488 Per is at a temperature of ~ 800 K. While comparably warm dust with τ orders of magnitude smaller than at V488 Per may orbit some main sequence stars, such small quantities of dust could easily be generated by asteroidal collisions near these stars. By contrast, the large τ at V488 Per indicates a recent collision of planet-mass objects (Melis et al 2010). If these warm grains radiate like blackbodies, then they lie only ~ 0.06 AU from the star. This semimajor axis is comparable to that characteristic of many transiting planets discovered by NASA's Kepler satellite.

Based on the data given in various published papers – these include photometric distance, proper motion, radial velocity, lithium abundance, and chromospheric activity – there seems to be little doubt that V488 Per is a bona fide member of the α Per cluster and it has been so classified in three of the papers cited in Table 1. In addition we can add new determinations of radial velocity, proper motion, and lithium abundance that buttress previous work on this star.

Concerning radial velocity, archival Keck/HIRES observations of V488 Per obtained by Dr. I. N. Reid on UT 12 December 1997 were acquired from the Keck Observatory Archive[‡]. We analyzed this high quality echelle spectrum and found a heliocentric velocity of 1.8 ± 0.5 km/s which agrees reasonably well with previous radial velocity

[‡] <http://www2.keck.hawaii.edu/koa/public/koa.php>

determinations by Mermilliod et al (2008; -0.31 ± 0.15 km/s) and Prosser (1992; -0.1 ± 0.6 km/s). All of these measured radial velocities are characteristic of stars in α Per (see, e.g., Table 4 in Prosser 1992).

From the HIRES spectrum we measured the equivalent width (EW) of the 6708 Å lithium absorption line to be ~ 200 mÅ. This is the EW anticipated for an early K-type star of age ~ 60 Myr; in Figure 3 of Zuckerman & Song (2004) this EW lies just below the EW of most of the plotted 30 Myr old members of the Tucana Association and near the top of the range of EW for ~ 100 Myr old Pleiades members.

We computed the proper motion of V488 Per by comparing positions in the 2MASS and WISE catalogs that are separated by epochs 10.1 years apart. We derive proper motions of $+15.7 \pm 6.6$ and -24.9 ± 9.1 mas/yr in R.A. and Decl., respectively. These values compare well with those given in the USNO-B1 (16, -24) and the PPMXL (15.9, -26.4) catalogs.

Because τ is so large for V488 Per compared to all other known dusty main sequence stars, one must consider the possibility of contamination by radiation from a background object. The best spatial resolution image of the field is likely that obtained with HST by Patience et al (2002). The HST/NICMOS camera and F140W filter revealed no source of $1.4 \mu\text{m}$ emission other than the star.

To further confirm that the large IR excess is from the star, at our request, Dr. Charles Beichman and collaborators (see caption to Figure 4) obtained a seeing-limited image of V488 Per with a $3.8 \mu\text{m}$ (Lp) filter and the NIRC2 camera on the Keck II telescope at Mauna Kea Observatory. This image shows only a single source of FWHM $\sim 0.6''$ and approximately circular shape (Figure 4). Thus, there can be little doubt that the strong IR excess emission is indeed associated with V488 Per.

An additional concern is whether V488 Per might be a dusty, first ascent "Phoenix Giant" star (Melis 2009; Melis et al 2009) well to the background of the α Per cluster. Some Phoenix Giants have very large τ and hot and cool dust with SEDs similar to that of V488 Per. If V488 Per is actually a Phoenix Giant, then the fact that the photometric distance, radial velocity, and proper motion of V488 Per are all consistent with membership in α Per would have to be regarded as simply a strange coincidence. As outlined in Melis et al (2009), we use line ratio diagnostics presented in Strassmeier & Fekel (1990) and the Keck/HIRES spectrum to evaluate whether V488 Per is a luminosity class III or class V star. We find that V488 Per is a luminosity class V star. All K-type Phoenix Giants exhibit luminosity class III line ratios when similar analysis is performed for them.

As an aftermath of collisions of planetary embryos, solar-type stars are most likely to display large quantities of warm dust particles during the last stages of the assembly of rocky planets in the terrestrial planet zone; this would be at ages between 30 and 100 Myr (Melis et al 2010). The age of V488 Per lies in this range and, so, this very dusty star can be added to the small sample of similar stars discussed by Melis et al.

HD 21375: This is a single-line, 31 day, spectroscopic binary according to Morrell &

Abt (1992).

HD 21641: This is a weak emission, shell, Be star (e.g., Briot 1986). Therefore we cannot be sure that the observed excess IR emission (Table 3, Figure 2) is due to a dusty debris disk rather than an outflowing ionized wind. If the latter, then the excess emission becomes apparent only at much longer wavelengths than is seen toward Be stars ψ Per and HR 1037 (both mentioned above). Future observations at far-IR wavelengths may distinguish between the two potential emission mechanisms.

HD 21855: This A-type may have weak excess emission at $22\ \mu\text{m}$ (W4) and perhaps also at $11.5\ \mu\text{m}$ (W3). At W4, the photosphere is expected to be 6.4 mJy. The measured WISE flux density is 10.2 ± 0.87 mJy, so excess emission at the $4.4\ \sigma$ level may be present. In the W3 band, the expected photosphere is 22.6 mJy and the WISE measured flux density is 23.5 ± 0.39 mJy, for a possible $2.3\ \sigma$ excess.

3.2. Evolution of Dusty Debris Disks with Time

Table 11 in Zuckerman et al (2011) presented infrared excess fractions at wavelengths of 24 and $70\ \mu\text{m}$ for various open clusters and nearby moving groups. Table 4 of the present paper repeats the $24\ \mu\text{m}$ column from their Table 11, but now with the addition of the $22\ \mu\text{m}$ excess fraction in the α Per cluster. Before comparing α Per to other clusters we consider some techniques for estimation of ages of stars in clusters and associations.

The two principal techniques for derivation of ages of young clusters are matching cluster members of various spectral types to theoretical pre-main sequence isochrones and identification of the location of the lithium depletion boundary. For a given cluster with age comparable to that of α Per and for which both age-dating methods have been applied, the lithium method generally yields an older age. Therefore, it is important to take into account how ages have been deduced when comparing the age of α Per to those of other clusters in Table 4.

Figure 5 presents color magnitude diagrams for α Per and for the Pleiades. The latter is clearly the older cluster. A quantitative measure of this age difference is suggested from the Li depletion analysis of Barrado y Navascues et al (2004) who derive ages of 50 ± 5 , 85 ± 10 , and 130 ± 20 Myr for IC 2391, α Per, and the Pleiades, respectively. In comparison, isochrone ages for these clusters have been given as 35-40 Myr (IC 2391, Barrado y Navascues et al 2004; Torres et al 2008), 50-80 Myr (α Per, Makarov 2006; Prosser 1992), and ~ 100 Myr (Pleiades, see references listed in Luhman et al 2005). Discussions of the age of α Per by Makarov (2006) and by Prosser (1992) illustrate that ages derived from main sequence fitting can be based on the upper main sequence, the lower main sequence, or both, and that the former is subject to uncertainties in the degree of convection overshooting.

The age of the AB Dor moving group has been a subject of considerable discussion (Luhman et al 2005; Janson et al 2007; Close et al 2007; Ortega et al 2007) with ages ranging from 50 Myr to the age of the Pleiades (≤ 120 Myr). This discussion is outlined

in Section 8 of Torres et al (2008) who present their own color-magnitude diagram of AB Dor members and who prefer an age of 70 Myr.

For M47 Rojo Arellano et al (1997) use main sequence fitting to derive an age of ~ 100 Myr, while for NGC 2451 an isochronal age of 60 Myr is deduced (references listed in Balog et al 2009).

Based on the discussion in the preceding paragraphs, one may see that the ages in Table 4 are weighted more toward isochrone fitting than Li depletion. This is in part because Li ages have been derived for only some of the listed clusters and associations. However, whatever the true absolute cluster ages, the relative ages as given in Table 4 should be quite reliable.

As noted in the Introduction, excepting the α Persei cluster, Spitzer surveyed stars in all the clusters and associations listed in Table 4. The listed $24\ \mu\text{m}$ Spitzer/MIPS excess statistics are usually dominated by F, G and K type stars. In the Zuckerman et al (2011) paper, a ratio of MIPS measured $24\ \mu\text{m}$ flux density to expected photospheric flux of 1.16 or greater was deemed sufficient to establish the presence of an excess. This ratio was not uncharacteristic of excess criteria employed in other references listed in Table 4. Unfortunately, given the size of the WISE catalog errors in flux density at $22\ \mu\text{m}$ and the greater distance from Earth of the α Per cluster compared to a majority of the regions listed in Table 4, this level of sensitivity to excess emission was obtained only for most of the B-type stars in α Per. Even for an α Per A-type star, the excess emission would have to be at a level $\sim 60\%$ of the photosphere for it to satisfy the excess criterion set out in Section 2.2.

As a result, it is not possible at this time to sensibly compare excess fractions in α Per and other Table 4 clusters. That is, the excess statistics listed for the α Per cluster pertain only to B- and A-type members and, to qualify as an excess star, the measured $22\ \mu\text{m}$ flux density must often be as large as 1.5 times the photospheric flux. In contrast, the statistics for other listed regions in Table 4 usually are dominated by F, G and K-type stars and represent excesses that need only be ~ 1.2 times the photospheric flux. Since many stars in, for example, the Zuckerman et al (2011) lists have $24\ \mu\text{m}$ flux density between 1.2 and 1.5 times that of the photosphere, there can be little doubt that some A-type stars in the α Per cluster have excess emission not far below our defined level of excess and will have been missed with our WISE survey. Such caveats apply even more strongly to the many F- and G-type stars listed in Tables 1 and 2.

We may summarize what might reasonably be inferred from Table 4 as follows: Although the α Persei cluster may be deficient in dusty debris disks relative to other Table 4 clusters and moving groups of comparable age, because (1) the α Per statistics pertain only to B- and A-type stars whereas the statistics for the other groups are dominated by later-type stars, and (2) the WISE sensitivity to dusty debris at these α Per stars was not quite as good as Spitzer sensitivities in these other groups, it would be premature to draw any firm conclusions. Additional infrared measurements at 22 or $24\ \mu\text{m}$ are unlikely to come before the James Webb Space Telescope is operational. Before then, perhaps the best way to determine if debris disks in α Per are relatively scarce

would be to confirm or deny whether the A- and B-type stars in Table 2 are actual cluster members (none have $22\ \mu\text{m}$ excess emission). If most are members, then as indicated by statistics given in the Note to Table 4, the implication of a real relative deficiency of debris disks in the α Per cluster would be suggestive, if not totally convincing.

α Per is at the same or smaller absolute Galactic latitude than all Table 4 clusters and moving groups excepting M47. Therefore, in the event that background cirrus contamination could introduce an error in the disk fraction, this error would most likely be in the sense to increase the apparent number of dusty stars in α Per relative to other clusters and associations in Table 4.

As remarked in the notes to Table 4, the tabulated excess fraction of the α Per cluster is for a wavelength of $22\ \mu\text{m}$, but at $24\ \mu\text{m}$ for all other entries. Dusty debris disks studied by IRAS and Spitzer at far-IR wavelengths have typical temperatures of ~ 80 K. For this temperature the flux density will be ~ 1.5 times larger at $24\ \mu\text{m}$ than at $22\ \mu\text{m}$. Given our $5\ \sigma$ WISE detection threshold at $22\ \mu\text{m}$ (see Section 2.2), we checked among Table 1 and 2 stars, but not listed in Table 3, for any B- or A-type stars with at least $3.3\ \sigma$ of apparent excess emission; that is, for stars for which "W4 meas" is greater by at least $3.3\ \sigma$ than "W4 Photo" (see the header to Table 3). Other than HD 21855 with $4.4\ \sigma$ of possible excess emission (see Section 3.1), no such stars were found. Thus, the difference between 22 and $24\ \mu\text{m}$ should not alter the ratio of percentage of excess stars in α Per compared to excess percentages in other listed clusters.

Dukes & Krumholz (2011; see also references cited therein) suggest that disk disruption events are no more likely in massive clusters than in low mass clusters. They cite observations that would indicate that, for most clusters, 90% of the stars disperse into the field within 10 Myr. The stellar binary fraction in α Per and other rich nearby clusters (Pleiades, Hyades, Praesepe) have been considered in various papers. Patience et al (2002) note that the distribution of semimajor axes of binary stars in these four clusters peaks at 5 AU, "a significantly smaller value" than for stars in the solar neighborhood. Morrell & Abt (1992) comment on the relatively small number of spectroscopic binaries among B- and A-type stars in α Per and in the Pleiades. Makarov (2006) notes that counting all types of binaries in α Per, only $\sim 20\%$ of members are binaries which is "modest even compared with field G-dwarfs and much smaller than the binarity rate in the Hyades and Pleiades." Calculations – utilizing the known characteristics of clusters and associations listed in Table 4 – of the (relative) frequency of close stellar encounters might be of interest.

4. CONCLUSIONS

We assembled what likely is the most complete listing of probable and possible B-type through G-type members of the nearby α Persei cluster. We then correlated sources in the final WISE catalog with cluster members and found 11, or possibly 12, with excess emission above the photosphere at $22\ \mu\text{m}$ (and sometimes also at other WISE wavelengths), that we interpret as due to a surrounding dusty debris disk. In addition,

a few B-type stars display excess emission consistent with production in an outflowing wind. Of the probable B- and A-type cluster members, 14% display excess emission (from an orbiting dusty debris disk) at a wavelength of 22 μm . If B- and A-type stars that are possible members are included in the statistics, the percentage of excess stars could be as small as 11.6%. For later-type stars, the WISE sensitivity is inadequate to detect many (most?) of the debris disks that likely orbit stars in the cluster.

V488 Per is the most interesting dusty star in the α Persei cluster. The luminosity of orbiting dust grains is at least 16% of the bolometric luminosity of this K-type star; this is a far larger excess luminosity percentage than that previously known at any main sequence star. Although there are numerous reasons to include V488 Per as a bona fide member of the cluster, for confirmation, a measurement of its trigonometric parallax would be worthwhile. Recently, Melis et al (2012b) identified a young star with, initially, a fractional excess luminosity at mid-IR wavelengths almost as large as that at V488 Per. However, the excess at this young star recently disappeared – in the space of only a few years. Thus, the excess infrared emission at V488 Per bears careful watching during the coming years.

Previously we considered the final era of the accretion of rocky planets around solar mass stars in a region analogous to that where the four rocky planets of the Solar System reside (Melis et al 2010). By assembling a list of stars known to contain large quantities of warm dust grains, we found that this era occurs at stellar ages from 30 to 100 Myr. With its very strong mid-IR excess emission and its ~ 60 Myr age, V488 Per can now be included among those stars that are orbited by large rocky bodies in the terrestrial planet zone. By contrast, Melis et al (2012a) find that the dominant era of rocky planet formation around stars with masses a few times that of the Sun is over by about 30 Myr; our study of the ~ 60 Myr old α Persei cluster is consistent with this finding. Specifically, among 70 late-B to early-F type α Per cluster members, WISE reveals none with the massive amounts of warm dust that would herald the aftermath of a collision of planetary embryos.

Future observations at far infrared and/or submillimeter will be necessary to characterize the properties of the α Per debris disks. For V488 Per such observations will be especially important because, unlike most other main sequence stars that are orbited by large quantities of warm dust particles but little or no cold dust, V488 Per appears to be orbited by large amounts of both warm and cold dust.

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Table 1: High-Fidelity α Persei Cluster Members

Star Name	RA (J2000)	Dec (J2000)	pmRA (mas/yr)	pmDec (mas/yr)	Spectral type	He	Pr?	Ma?	St?	Me?	Rob?	Ran?
BD+48 851	03 07 49.8	+49 06 23	26.9±1.9	−23.6±1.9	F6V	12	y	y		y		
TYC 3315 1159 1	03 11 16.8	+48 10 37	27.4±1.9	−28.0±1.8	F9V	94	y	y				
HD 19655	03 11 41.1	+48 03 15	31.0±1.4	−31.1±1.4	F2Vn	104	y	y				
HD 19624	03 11 42.9	+52 09 48	24.8±1.1	−25.1±1.2	B5	145	y?	y				
BD+49 868	03 11 50.0	+50 22 47	24.0±1.6	−23.4±1.6	F5V	135	y	y		y	y	
HD 19767	03 12 43.3	+47 50 19	23.4±1.3	−25.3±1.3	F0Vn	151	y	y			y	
HD 19805	03 13 05.2	+49 00 34	25.3±1.7	−25.6±1.8	B9.5V	167	y	y			y	
TYC 3319 446 1	03 13 07.4	+49 34 04	24.1±4.2	−30.2±3.8	G	174	y	y	y?	y		
HD 19893	03 13 50.3	+49 34 08	26.1±1.2	−25.3±1.3	B9V	212	y	y			y	
BD+48 871	03 15 23.6	+49 26 25	22.7±1.6	−21.6±1.6	F7V	270	y	y		y	y	
TYC 3319 9 1	03 15 58.9	+50 24 19	19.0±2.2	−17.5±2.0	F7	299	y	y		y		
BD+49 889	03 16 23.2	+49 37 33	24.2±1.9	−21.8±1.9	F5V	309	y	y		y		
HD 20191	03 16 49.1	+51 13 05	24.1±1.4	−23.9±1.5	B9	333	y	y			y	
BD+49 892	03 16 59.4	+49 55 36	22.9±2.0	−21.8±2.0	F7V	334	y	y	y	y		
BD+48 876	03 17 20.5	+49 30 01	24.1±1.9	−26.1±1.9	F7V	338	y	y		y		
AP 119	03 17 31.4	+48 51 51	25.2±1.3	−23.5±2.2	K2		y					
TYC 3319 306 1	03 17 36.9	+48 50 08	17.7±2.3	−19.6±2.2	G3	350	y	y		y		y
AP 121	03 17 42.1	+49 01 46	21.2±1.4	−21.1±1.3	G5		y*y		y	?		
HD 20282	03 17 43.2	+50 21 40	31.2±1.6	−32.3±1.7	A0	357		y				
BD+49 896	03 18 01.7	+49 38 39	21.0±1.9	−23.0±1.9	F4V	361	y	y		y		
BD+49 897	03 18 05.2	+49 54 22	24.0±1.6	−24.0±1.6	F6V	365	y	y			y	
HD 20344	03 18 23.9	+50 33 21	26.8±1.3	−26.9±1.5	A0	379	y?	y			y	
<i>continued on next page</i>												

Table 1: (continued)

Star Name	RA (J2000)	Dec (J2000)	pmRA (mas/yr)	pmDec (mas/yr)	Spectral type	He	Pr?	Ma?	St?	Me?	Rob?	Ran?
V522 Per	03 18 27.4	+47 21 15	17.6 \pm 3.0	-26.9 \pm 2.7	G3	373	y	y				
29 Per	03 18 37.7	+50 13 20	22.7 \pm 1.0	-26.7 \pm 1.1	B3V	383	y	y			y	
HD 20391	03 18 44.8	+49 46 12	21.5 \pm 1.8	-25.8 \pm 1.8	A2V	386	y	y			y	
TYC 3319 589 1	03 18 50.3	+49 43 52	20.1 \pm 2.2	-28.7 \pm 2.1	G0	389	y	y				
V524 Per	03 18 59.3	+48 50 35	25.6 \pm 1.6	-23.7 \pm 2.0	K5		y					
31 Per	03 19 07.6	+50 05 42	21.9 \pm 1.2	-26.3 \pm 1.2	B5V	401	y	y				
HD 20475	03 19 42.2	+48 54 49	22.7 \pm 1.2	-27.1 \pm 1.3	F2V	421	y	y			y	y
HD 20487	03 19 47.2	+48 37 41	23.6 \pm 1.9	-24.4 \pm 2.0	A0Vn	423	y	y			y	
AP 126	03 19 57.3	+49 04 21	23.9 \pm 8.5	-21.6 \pm 8.5	M4		y					
HD 20510	03 20 06.3	+50 58 07	23.0 \pm 0.9	-26.4 \pm 1.1	B9V	441	y?	y			y	
HD 20537	03 20 23.7	+51 37 06	27.1 \pm 0.9	-26.5 \pm 1.0	B9	450		y			y	
TYC 3315 1781 1	03 20 39.3	+47 29 22	22.5 \pm 1.8	-18.8 \pm 1.7	F8V	453	y?	y	y	y		y?
AP 97	03 20 41.9	+48 24 38	23.9 \pm 1.4	-25.3 \pm 1.3	G6.5		y ^a		y	y		y
AP 131	03 20 56.5	+49 20 43	23.5 \pm 7.6	-26.9 \pm 7.6	M4		y					
V625 Per	03 21 06.5	+48 26 13	18.7 \pm 1.8	-30.8 \pm 4.5	G9		y ^a		y	y		y
AP 134	03 21 20.5	+47 53 15	23.7 \pm 7.9	-20.7 \pm 7.9	M3		y					
BD+47 808	03 21 30.2	+48 29 38	23.2 \pm 1.2	-24.1 \pm 1.2	F1IVn	481	y	y			y	
BD+48 892	03 21 40.2	+49 07 13	24.0 \pm 1.3	-26.6 \pm 1.4	F3IV-V	490	y	y		y		
V459 Per	03 21 58.6	+49 12 53	23.5 \pm 1.3	-25.7 \pm 1.3	F0IV	501	?	y				
V529 Per	03 22 06.8	+47 34 07	17.3 \pm 4.4	-28.3 \pm 4.0	K2		y					y
V484 Per	03 22 21.9	+49 08 28	21.9 \pm 2.5	-25.0 \pm 2.3	G6V	520	y	y				y
HD 20714	03 22 26.3	+51 39 39	19.6 \pm 1.3	-20.1 \pm 1.4	A7Vn	522	?	y				

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Table 1: (continued)

Star Name	RA (J2000)	Dec (J2000)	pmRA (mas/yr)	pmDec (mas/yr)	Spectral type	He	Pr?	Ma?	St?	Me?	Rob?	Ran?
V575 Per	03 23 13.2	+49 12 48	20.6 \pm 1.3	-26.5 \pm 1.4	B5V	557	y	y			y	
BD+47 815	03 23 40.3	+47 57 30	24.9 \pm 1.8	-28.4 \pm 1.8	F3V	577	?	y	y?			y?
HD 20842	03 23 43.1	+51 46 13	23.2 \pm 1.4	-23.9 \pm 1.5	A0V	575	y	y				
HD 20863	03 23 47.3	+48 36 16	23.2 \pm 1.5	-27.0 \pm 1.5	B9V	581	y	y			y	y
BD+ 49 914	03 23 55.1	+50 18 24	23.1 \pm 1.6	-26.1 \pm 1.6	F5V	588	y	y				
HD 20903	03 24 06.5	+46 17 19	25.4 \pm 1.1	-23.9 \pm 1.1	A2			y				
AP 109	03 24 06.7	+49 24 52	15.4 \pm 8.4	-29.6 \pm 6.8	M3		y ^a					y
Melotte 20 601	03 24 17.1	+49 39 00	21.5 \pm 1.5	-22.2 \pm 1.5	G6	601	n		y	y		
V461 Per	03 24 19.2	+49 13 16	21.0 \pm 1.5	-24.8 \pm 1.5	A8V	606	y?	y				y?
α Per	03 24 19.4	+49 51 40	22.3 \pm 0.6	-26.1 \pm 0.7	F5Iab	605	y	y			y	
AP 14	03 24 19.9	+48 47 20	22.8 \pm 1.2	-25.1 \pm 0.5	G4		y			y		y
V485 Per	03 24 25.1	+48 48 21	15.1 \pm 6.5	-29.3 \pm 6.7	K5							y
BD+49 918	03 24 25.6	+50 19 34	22.5 \pm 1.4	-27.5 \pm 1.4	F0V	609	y	y				
HD 20931	03 24 30.0	+49 08 24	22.9 \pm 1.9	-25.6 \pm 2.0	A1V	612	y	y			y	
BD+47 816	03 24 47.1	+48 24 42	22.0 \pm 1.5	-26.3 \pm 1.5	F4V	621	y	y		y	y	
V531 Per	03 24 49.7	+48 52 18	23.2 \pm 3.0	-27.2 \pm 2.8	G5	622	y	y	y			y
HD 20961	03 24 52.1	+47 54 54	23.7 \pm 1.6	-26.0 \pm 1.7	B9.5V	625	y	y				
BD+46 745	03 24 54.6	+47 24 54	22.1 \pm 1.4	-25.9 \pm 1.4	F4V	632	y	y			y	
HD 20969	03 25 04.4	+49 47 43	22.0 \pm 1.3	-25.7 \pm 1.4	A8V	635	y	y				
HD 20986	03 25 10.0	+49 15 06	22.0 \pm 1.3	-24.4 \pm 1.3	A3Vn	639	y	y				
AP 25	03 25 16.2	+48 22 24	15.6 \pm 4.5	-25.1 \pm 4.0	K0		y			y		y
HD 21005	03 25 20.7	+49 18 58	21.5 \pm 1.3	-25.1 \pm 1.3	A5Vn	651	y	y				

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Table 1: (continued)

Star Name	RA (J2000)	Dec (J2000)	pmRA (mas/yr)	pmDec (mas/yr)	Spectral type	He	Pr?	Ma?	St?	Me?	Rob?	Ran?
TYC 3320 1768 1	03 25 37.6	+50 19 18	19.8 \pm 1.5	-25.6 \pm 1.5	F5V	660	y?	y	y?			
HD 21046	03 25 37.7	+47 01 14	22.6 \pm 1.0	-25.6 \pm 1.0	A7V	665	y	y				
V576 Per	03 25 57.4	+49 07 15	21.8 \pm 1.5	-28.2 \pm 1.5	B7V	675	y	y			y	
V688 Per	03 26 04.2	+48 48 07	21.6 \pm 2.2	-22.7 \pm 2.2	F9V	684	y	y	y	y		y
HD 21091	03 26 10.8	+48 23 03	24.3 \pm 1.4	-28.7 \pm 1.5	B9.5V	692	y?	y			y	
AP 38	03 26 19.3	+49 13 32	20.6 \pm 1.5	-28.1 \pm 3.0	G3	696	y		y	y		y
V532 Per	03 26 22.2	+49 25 37	18.4 \pm 3.0	-19.0 \pm 2.7	G2-3V	699	y	y				y
V628 Per	03 26 25.3	+48 20 07	20.5 \pm 1.7	-27.2 \pm 2.8	G5		y			y		y
HD 21122	03 26 32.6	+47 15 59	24.5 \pm 1.1	-28.6 \pm 1.2	A0	710		y			y	
AP 158	03 26 33.7	+50 13 54	22.1 \pm 1.5	-25.4 \pm 0.9	K0		y		y	y		
HD 21117	03 26 39.4	+50 50 47	24.9 \pm 1.2	-27.4 \pm 1.4	B8	703		y			y	
BD+47 825	03 26 39.2	+47 52 56	21.5 \pm 1.5	-26.0 \pm 1.5	F2Vn	721	?	y				
TYC 3320 1715 1	03 26 40.7	+48 46 37	20.4 \pm 1.9	-25.8 \pm 1.9	F4V	715	y	y				y
TYC 3320 818 1	03 26 43.9	+49 54 34	18.3 \pm 2.3	-23.4 \pm 2.3	G0V	709	y	y				y
AP 51	03 26 50.7	+48 47 31	20.0 \pm 2.2	-23.5 \pm 2.1	F7V	727	y	y				y
BD+48 916	03 27 03.2	+48 47 13	22.0 \pm 1.9	-25.4 \pm 1.9	F6V	733	y?	y		y		y?
HD 21181	03 27 05.1	+48 12 20	23.9 \pm 1.3	-25.5 \pm 1.4	BVn	735	y	y			y	
AP 161	03 27 18.9	+47 25 24	22.6 \pm 7.3	-19.9 \pm 7.0	M3		y					
HD 21239	03 27 37.6	+48 16 23	23.4 \pm 1.6	-27.1 \pm 1.7	A3Vn	756	?	y				
AP 58	03 27 37.8	+48 59 29	15.8 \pm 2.2	-26.1 \pm 2.1	F9V	750	y	y				y
HD 21238	03 27 38.9	+49 36 00	22.6 \pm 1.5	-25.3 \pm 1.5	B9V	747		y			y	
V534 Per	03 27 51.0	+49 12 10	20.7 \pm 0.5	-24.9 \pm 1.4	K2		y					y

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Table 1: (continued)

Star Name	RA (J2000)	Dec (J2000)	pmRA (mas/yr)	pmDec (mas/yr)	Spectral type	He	Pr?	Ma?	St?	Me?	Rob?	Ran?
TYC 3320 2239 1	03 27 55.0	+49 45 37	18.3 \pm 2.3	-24.7 \pm 2.2	F9V	767	y	y	n?	y		
HD 21279	03 27 55.8	+47 44 09	23.9 \pm 1.7	-27.4 \pm 1.8	B8.5V	775	y	y				
HR 1034	03 28 03.1	+49 03 47	22.9 \pm 1.3	-26.0 \pm 1.3	B5V	774	y	y			y	
HD 21302	03 28 18.6	+49 57 10	22.5 \pm 1.7	-24.6 \pm 1.7	A1Vn	780	y	y				y
V488 Per	03 28 18.7	+48 39 48	15.7 \pm 6.6	-24.9 \pm 9.1	K0		y			y		y
BD+48 923	03 28 31.5	+48 56 27	22.2 \pm 1.9	-27.1 \pm 1.9	F4V	799	y	y				y
BD+49 939	03 28 34.7	+50 16 01	22.6 \pm 1.4	-25.7 \pm 1.4	F3IV-V	794	y?	y		y		
HD 21345	03 28 38.0	+49 23 15	21.4 \pm 1.4	-25.0 \pm 1.4	A5Vn	802	?	y				
HR 1037	03 28 52.3	+49 50 54	21.7 \pm 1.6	-26.1 \pm 1.6	B6Vn	810	y	y			y	
HD 21375	03 28 53.6	+49 04 13	24.6 \pm 1.9	-31.2 \pm 2.0	A1V	817	y	y				y
Melotte 20 828	03 28 59.6	+48 14 08	19.2 \pm 1.3	-26.0 \pm 1.7	F8	828	y		?	y		y
HD 21398	03 29 07.6	+48 18 10	22.5 \pm 1.5	-26.9 \pm 1.6	B9V	831	y	y				
TYC 3316 904 1	03 29 08.3	+48 10 51	22.3 \pm 1.4	-27.6 \pm 1.0	F6	833	y			y		
AP 176	03 29 19.0	+46 07 27	21.7 \pm 7.6	-27.6 \pm 7.4	M4.2		y					
HD 21428	03 29 22.0	+49 30 32	19.4 \pm 2.2	-24.3 \pm 2.1	B3V	835	y	y				y
TYC 3320 1057 1	03 29 24.9	+48 57 45	24.1 \pm 2.0	-25.6 \pm 2.0	F7V	841	y	y				y
BD+47 837	03 29 26.2	+48 12 12	22.6 \pm 1.9	-28.1 \pm 1.9	F9V	848	y	y	y	y		y
BD+48 931	03 29 46.9	+49 00 34	23.7 \pm 1.5	-28.0 \pm 1.5	F6V	863	n	y		y		y
BD+47 839	03 29 46.9	+47 34 58	18.8 \pm 1.5	-27.7 \pm 1.6	F0	876	y	y				y
HD 21480	03 29 47.0	+49 09 13	27.5 \pm 1.5	-33.3 \pm 1.6	A7V	862	y	y				
HD 21481	03 29 50.0	+47 58 37	22.9 \pm 1.1	-28.8 \pm 1.4	A0Vn	875	n?	y				y
HD 21479	03 29 51.8	+49 12 49	20.2 \pm 1.2	-27.2 \pm 1.4	A1IVn	868	y	y				

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Table 1: (continued)

Star Name	RA (J2000)	Dec (J2000)	pmRA (mas/yr)	pmDec (mas/yr)	Spectral type	He	Pr?	Ma?	St?	Me?	Rob?	Ran?
HD 21527	03 30 19.3	+48 29 57	21.6±1.1	−28.3±1.1	A7IV	885	y	y			y	y
V465 Per	03 30 34.0	+47 37 41	22.8±1.3	−24.5±1.4	A6Vn	906	y	y				
HR 1051	03 30 36.9	+48 06 13	24.1±1.5	−23.5±1.6	B8V	904	y	y			y	
Melotte 20 917	03 30 47.6	+47 53 22	22.3±1.3	−27.5±1.4	F4	917	y			y		y
AP 183	03 30 56.8	+50 00 51	19.6±7.5	−30.1±6.5	M3		y					
HD 21600	03 31 14.6	+49 42 22	21.7±1.4	−24.7±1.4	A6Vn	921	y	y			y	
BD+48 937	03 31 29.0	+48 59 28	21.4±1.5	−26.9±1.4	F9.5V	935	y	y				y
HD 21619	03 31 30.2	+49 54 07	21.7±1.4	−26.1±1.4	A6V	931	y	y			y	
HD 21641	03 31 33.1	+47 51 45	22.3±1.4	−25.9±1.5	B8.5V	955	y	y			y	
BD+49 957	03 31 44.2	+49 32 04	21.8±1.5	−25.5±1.6	F3V	944	y	y				y
AP 189	03 31 44.9	+49 33 04	16.1±2.6	−21.1±1.5	K3		y?*y					y
HD 21672	03 31 53.9	+48 44 06	25.2±1.4	−29.0±1.5	B8V	965	y	y				y
TYC 3316 956 1	03 31 54.2	+48 31 38	22.6±1.7	−26.9±1.7	F8V	968	y	y	y	y		y
BD+48 944	03 31 55.8	+48 35 02	25.3±1.4	−30.7±1.4	A4V	970	y	y				
BD+49 958	03 31 59.5	+49 52 10	24.0±1.3	−25.9±1.3	F1V	958	n?	y			y	
V396 Per	03 32 08.6	+48 01 24	23.2±1.4	−23.5±1.5	B8III	985	y	y			y	
V689 Per	03 32 10.2	+49 08 29	17.3±7.4	−25.3±7.3	G5V		y					y
AP 196	03 32 19.3	+47 04 27	26.4±7.4	−31.7±7.4	K3		y			y		
V537 Per	03 32 30.7	+49 10 35	20.4±1.2	−27.2±1.1	G8		y					y
HD 232804	03 32 31.9	+51 29 22	21.0±1.4	−22.6±1.4	F5	972	y	y				
HD 21855	03 33 22.2	+47 25 19	21.4±1.4	−27.6±1.4	A0	1056	?	y			y	
BD+49 967	03 33 54.4	+50 17 48	21.5±1.4	−27.8±1.4	A6me	1050	y?	y			y	

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Table 1: (continued)

Star Name	RA (J2000)	Dec (J2000)	pmRA (mas/yr)	pmDec (mas/yr)	Spectral type	He	Pr?	Ma?	St?	Me?	Rob?	Ran?
BD+50 784	03 33 58.9	+50 52 56	18.7 \pm 2.0	-26.0 \pm 1.9	F6	1045	y	y				
HD 21931	03 34 12.9	+48 37 03	22.5 \pm 1.5	-27.2 \pm 1.6	B9V	1082	y	y				
BD+48 950	03 34 21.6	+48 39 36	22.2 \pm 1.6	-29.0 \pm 1.6	A2	1084	y	y				
TYC 3325 239 1	03 35 05.0	+50 54 45	18.8 \pm 2.7	-22.3 \pm 2.5	G0:	1086	y*y	y	y	y		
TYC 3321 1655 1	03 35 08.7	+49 44 39	19.1 \pm 2.7	-28.5 \pm 2.5	G4	1101	y	y		y		
HD 22136	03 35 58.5	+47 05 28	21.3 \pm 1.2	-24.5 \pm 1.2	B8V	1153	y	y			y	
V540 Per	03 36 22.0	+49 09 21	20.3 \pm 0.9	-24.9 \pm 1.0	K0	1143	y					
ψ Per	03 36 29.4	+48 11 33	19.4 \pm 1.2	-28.9 \pm 1.2	B5Ve	1164	n	y			y	
TYC 3317 1064 1	03 36 31.8	+48 39 17	17.6 \pm 1.9	-27.7 \pm 1.9	F7	1160	y	y				
TYC 3321 187 1	03 36 55.1	+48 49 43	20.8 \pm 1.9	-27.8 \pm 1.9	F7	1180	y	y		y		
TYC 3317 16 1	03 36 57.7	+48 44 46	19.2 \pm 2.6	-29.5 \pm 2.5	F7	1185	y*y	y		y		
AP 229	03 37 27.5	+47 33 44	16.6 \pm 6.4	-30.5 \pm 6.4	K8		y					
HD 22401	03 38 15.6	+47 34 37	20.3 \pm 1.3	-27.4 \pm 1.4	A0V	1259	y	y			y	
HD 22440	03 38 35.1	+48 35 37	19.4 \pm 1.6	-28.3 \pm 1.6	A2	1260	y	y			y	
TYC 3313 1551 1	03 38 51.0	+46 36 12	20.6 \pm 1.7	-25.9 \pm 1.7	G1			y				
AP 248	03 41 04.8	+49 09 32	22.6 \pm 6.9	-29.2 \pm 6.8	M3		y					
HD 232823	03 41 40.9	+51 16 35	23.6 \pm 1.2	-30.1 \pm 1.3	F2	1349	y?	y				

Note – Source names are from SIMBAD or VizieR. RA and Dec are from 2MASS. Most listed proper motions are from the Tycho-2 or UCAC3 catalog. He = Heckmann et al 1956; Pr = Prosser 1992, if * is present, then also Prosser 1994; Ma = Makarov 2006; St = Stauffer et al 1993; Me = Mermilliod et al 2008; Rob = Robinchon et al 1999; Ran = Randich et al 1996. ^a = cluster member from Prosser et al 1998. In the cited papers, y = yes, member; y? = probably member; ? = membership uncertain; n? = probably nonmember; n = nonmember. These evaluations are taken directly from the cited papers and have not been reevaluated by the authors of the current study.

Table 2: Possible α Persei Cluster Members

Star Name	RA (J2000)	Dec (J2000)	pmRA (mas/yr)	pmDec (mas/yr)	Spectral type	He	Pr?	Ma?	St?	Me?	Rob?	Ran?
HD 17744	02 52 39.9	+48 48 59	24.7 \pm 1.4	-25.5 \pm 1.5	A0			y				
HD 18280	02 57 54.1	+48 52 43	23.2 \pm 1.6	-21.4 \pm 1.6	A2			y				
BD+50 703	03 07 04.1	+51 17 40	17.0 \pm 1.5	-19.3 \pm 1.4	F2V	7	?					
TYC 3318 1509 1	03 08 14.5	+49 50 21	23.5 \pm 3.3	-21.7 \pm 3.0	K0			y				
BD+47 772	03 08 23.7	+47 36 16	19.4 \pm 1.7	-25.7 \pm 1.6	F7	13						
HD 19458	03 09 24.2	+45 22 58	24.1 \pm 0.9	-23.1 \pm 1.0	A0			y				
HIP 14697	03 09 51.5	+48 28 18	23.6 \pm 1.9	-22.3 \pm 1.8	G3V	56	y*n	y	n		y	
V572 Per	03 15 48.7	+50 57 21	33.2 \pm 1.6	-35.2 \pm 1.7	A0	295		y				
HD 20135	03 16 01.5	+48 01 34	26.4 \pm 1.4	-18.4 \pm 1.4	A0p	285	y					
TYC 3319 915 1	03 17 24.0	+49 21 14	15.4 \pm 1.9	-24.7 \pm 1.9	G0	340	y?*y		y	n		
TYC 3319 219 1	03 18 43.7	+50 23 11	26.6 \pm 1.3	-23.1 \pm 1.3	F6IV-V	387	y?					
TYC 3703 665 1	03 20 39.6	+52 43 35	28.1 \pm 2.6	-38.2 \pm 2.5	G3			y				
HD 232778	03 21 00.1	+50 59 35	19.4 \pm 1.3	-19.2 \pm 1.4	F8	463						
HD 20701	03 22 03.5	+47 56 05	19.3 \pm 1.4	-23.3 \pm 1.4	A1V	507	n	y				
HD 21152	03 26 50.2	+47 54 58	20.5 \pm 1.7	-23.8 \pm 1.8	B9V	729	n?					
HD 232793	03 27 14.1	+50 52 44	23.2 \pm 1.5	-26.0 \pm 1.5	F5V	732	?	y				
TYC 3316 677 1	03 27 36.7	+47 23 18	17.1 \pm 1.5	-24.0 \pm 1.5	G1	761						
AP 68	03 28 13.6	+49 13 13	20.9 \pm 6.9	-20.5 \pm 6.8	K3							
AP 73	03 28 24.4	+48 53 46	15.2 \pm 2.3	-24.3 \pm 3.8	G3							
TYC 3320 778 1	03 29 03.7	+50 21 12	22.6 \pm 2.5	-23.6 \pm 0.5	G5	818						
HD 21490	03 29 32.1	+43 13 50	22.8 \pm 1.2	-26.3 \pm 1.2	F2			y				
AP 85	03 30 22.0	+48 57 18	16.3 \pm 9.3	-25.2 \pm 6.3	K5							

continued on next page

Table 2: (continued)

Star Name	RA (J2000)	Dec (J2000)	pmRA (mas/yr)	pmDec (mas/yr)	Spectral type	He	Pr?	Ma?	St?	Me?	Rob?	Ran?
Melotte 20 1102	03 34 42.8	+47 53 14	19.6 \pm 2.3	-24.9 \pm 2.2	G1V	1102	n?	y				?
BD+46 780	03 37 17.6	+47 20 54	27.9 \pm 1.1	-23.8 \pm 1.1	F3IV	1218	y?					
BD+51 756	03 39 02.9	+51 36 37	21.5 \pm 2.3	-34.1 \pm 2.2	G2	1234	y*y	y		?		
TYC 3313 2091 1	03 41 05.7	+45 47 38	16.8 \pm 1.3	-25.2 \pm 1.2	G1			y				
HD 23219	03 45 27.5	+47 39 37	21.6 \pm 1.2	-27.2 \pm 1.4	B9V			y				
HD 23287	03 45 53.2	+45 36 00	22.6 \pm 1.2	-28.5 \pm 1.3	A0			y				
HD 23255	03 45 54.7	+50 25 09	19.2 \pm 1.2	-26.2 \pm 1.2	A5			y				
HD 23690	03 49 01.0	+46 48 10	21.9 \pm 1.6	-26.4 \pm 1.7	A0			y				
HD 24260	03 53 39.5	+45 45 29	20.9 \pm 1.1	-26.0 \pm 1.2	A0			y				
HD 24980	04 00 20.5	+47 34 19	17.3 \pm 1.2	-25.9 \pm 1.2	A2			y				
HD 25109	04 01 50.0	+50 38 17	21.2 \pm 1.4	-29.6 \pm 1.5	A0			y				

Note – Source names are from SIMBAD or VizieR. RA and Dec are from 2MASS. Proper motions are from the Tycho-2 or UCAC3 catalog. He = Heckmann et al 1956; Pr = Prosser 1992, if * is present, then also Prosser 1994; Ma = Makarov 2006; St = Stauffer et al 1993; Me = Mermilliod et al 2008; Rob = Robinchon et al 1999; Ran = Randich et al 1996. In the cited papers, y = yes, member; y? = probably member; ? = membership uncertain; n? = probably nonmember; n = nonmember. These evaluations are taken directly from the cited papers and have not been reevaluated by the authors of the current study.

Table 3. Members of the α Persei Cluster with Excess Mid-Infrared Emission

Star	Spectral Type	Photo	W1 (mJy)			Photo	W2 (mJy)			Photo	W3 (mJy)			Photo	W4 (mJy)		
			Meas	Err	Ex		Meas	Err	Ex		Meas	Err	Ex		Meas	Err	Ex
HD 19624	B5	570	578	19.7	–	318	317	6.1	–	54.1	55.8	0.88	–	15.1	45.8	1.5	30.7
HD 19893	B9	466	480	14.6	–	261	262	4.6	–	44.4	56.1	0.83	11.7	12.5	35.4	1.6	22.9
V459 Per	F0	144	147	3.3	–	81	80	1.5	–	13.8	15.2	0.27	1.4	3.9	9.0	0.87	5.1
HD 21091	B9.5	339	335	8.7	–	190	182	3.5	–	32.2	34.3	0.54	2.1?	9.1	18.9	0.94	9.8
HD 21117	B8	348	353	9.1	–	195	191	3.5	–	33.3	37.2	0.55	3.9	9.4	17.8	1.0	8.4
HD 21122	A0	252	261	6.0	–	142	142	2.9	–	24.1	25.8	0.4	1.7?	6.8	13.7	1.0	6.9
V 488 Per	K0	21.9	51.0	1.1	29.1	9.3	55.4	1.1	46.1	2.1	40.9	0.6	38.8	0.57	75.7	2.2	75.1
HD 21375	A1	441	450	14.1	–	247	247	4.6	–	42.1	41.3	0.6	–	11.9	19.2	1.1	7.3
HD 21480	A7	234	239	5.5	–	132	132	2.6	–	22.4	24.1	0.4	1.7?	6.4	14.7	0.96	8.3
HD 21641	B8.5	609	609	21.3	–	340	343	6.6	–	57.7	70.7	1.0	13.0	16.2	39.9	1.3	23.7
BD+50 784	F6	111	116	2.5	–	60.4	62.2	1.2	–	10.8	12.9	0.24	2.1	3.1	8.54	0.9	5.4

Note – In addition to the above 11 stars, also HD 21855 may have weak excess emission in the W4 band. Details may be found in Section 3.1. See also discussion of HD 21641, V 488 Per, and HD 21375 in Section 3.1. The four WISE wavebands W1, W2, W3 and W4 are 3.35, 4.60, 11.56 and 22.09 μm , respectively.

Table 4. Infrared Excess Fractions in Clusters/Associations

Cluster/ Association	age (Myr)	24 μ m excess (#)	(%)	Reference
η Cha	6	9/16	56	Rebull et al (2008)
TW Hya Assoc.	8	7/23	30	Rebull et al (2008)
UCL/LCC	10	10/35	34	Rebull et al. (2008)
β Pic MG	12	7/30	23	Rebull et al (2008)
NGC 2547	30	16/38	42	Gaspar et al (2009)
Tuc/Hor/Columba	30	27/62	43.5	Zuckerman et al (2011)
IC 2391	40	6/26	23	Rebull et al (2008) & Gaspar et al (2009)
Argus Assoc.	40	5/8	62.5	Zuckerman et al (2011)
NGC 2451	60	12/38	32	Balog et al (2009)
α Persei	60	8/56 ^a	14 ^a	this paper
AB Dor MG	70	12/47	25.5	Zuckerman et al (2011)
Pleiades	100	10/73	14	Gorlova et al (2006)
M47	100	8/63	13	Rebull et al (2008)
Hyades	650	2/78	2.5	Gaspar et al (2009)
Praesepe	750	1/135	0.7	Gaspar et al (2009)

Note – ^aFor α Persei, these statistics pertain to stars in Table 1 of spectral types B and A and at a wavelength of 22 rather than 24 μ m. Should the excess IR emission at HD 21641 be due to an ionized outflowing wind rather than a dusty debris disk (see Section 3.1), then the entries for α Per in the third and fourth columns would read 7/56 and 12.5%, respectively. If the 12 A-type stars and B-star HD 23219 in Table 2 were to be added to the Table 1 stars, then entries in the third and fourth columns would read 8/69 and 11.6%, respectively. Three B-type stars from Table 1 with mid-IR excess emission (ψ Per, 29 Per, and HR 1037, see Section 3) are excluded from all entries in Table 4 and in this caption.

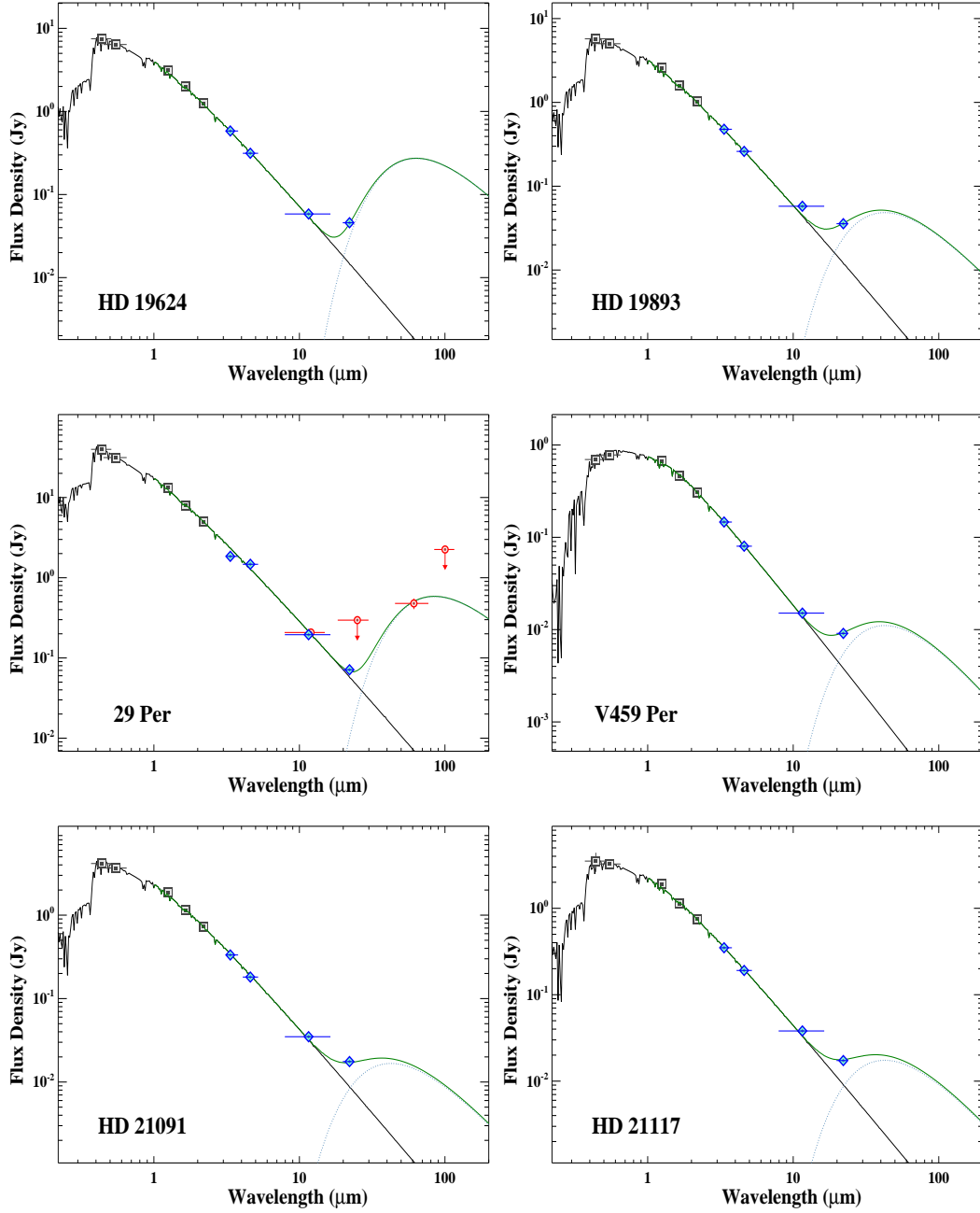


Figure 1. Spectral energy distributions (SED) for five α Persei cluster members in Table 3 with excess infrared emission and, in addition, the SED of 29 Per. Near infrared JHK data points are from the 2MASS catalog. The four diamonds are from WISE. Circles between 12 and 100 μm for 29 Per are from IRAS. The excess IR emission toward 29 Per is due to "cirrus" and not to an orbiting dusty debris disk (see Section 3.1). Long wavelength blackbodies have been added to the various panels for illustrative purposes. In all cases the blackbody temperature is 120 K, except for HD 19624 (80 K) and 29 Per (60 K).

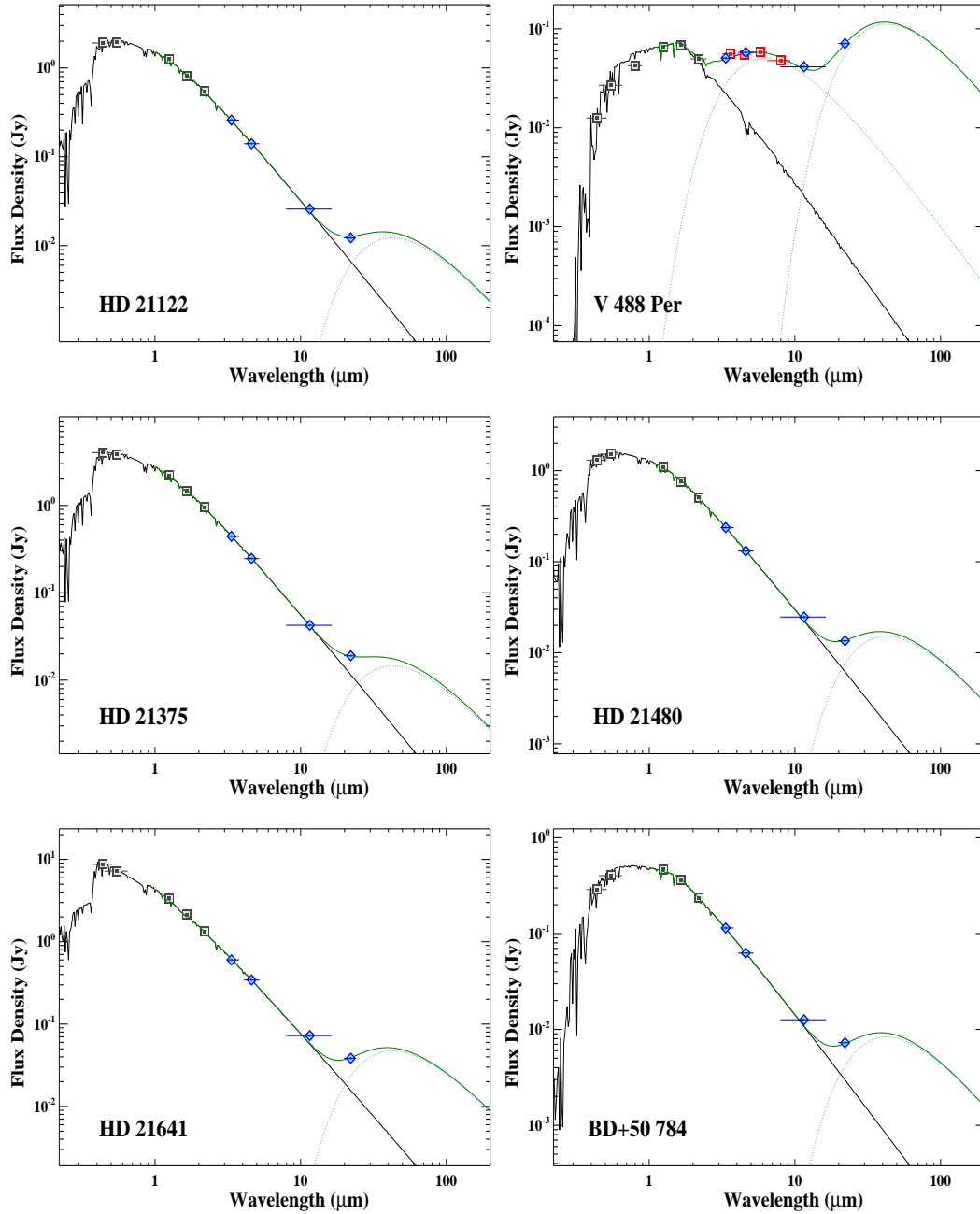


Figure 2. Same as for Figure 1. The square data points for V488 Per between 3.5 and 8 μm are from the IRAC camera on Spitzer. The blackbodies indicated on the V488 Per panel have temperatures of 820 and 120 K. The excess IR emission toward HD 21641 may not be due to a dusty debris disk (see Section 3.1). Long wavelength blackbodies have been added to the various panels for illustrative purposes. In all cases the blackbody temperature is 120 K.

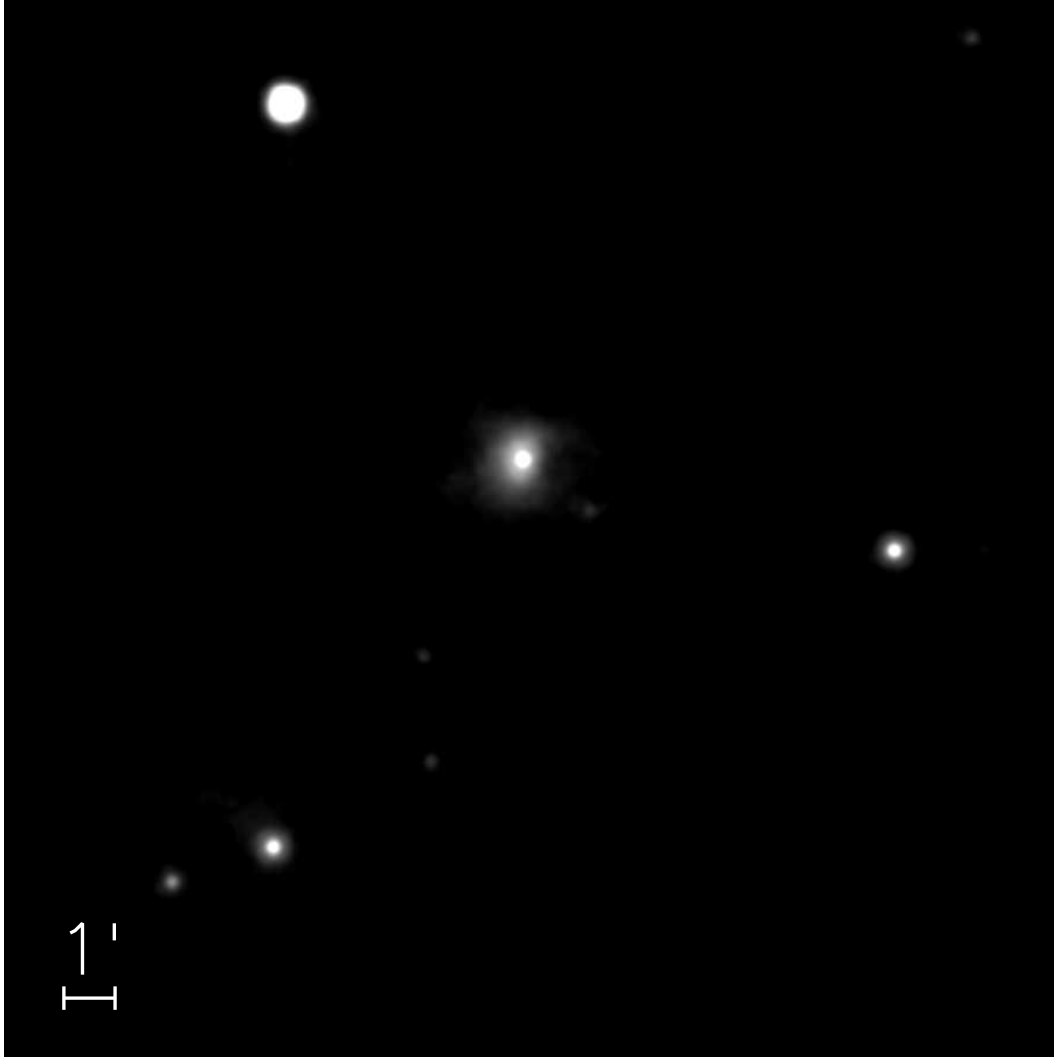


Figure 3. WISE $22\ \mu\text{m}$ image of the area surrounding and including 29 Per (center star in figure). North is up and East is left. The other sources are unresolved and give an idea of the point spread function. The image is presented with a logarithmic stretch. 29 Per is surrounded by an extended nebulosity. The scale bar is 1 arcminute.

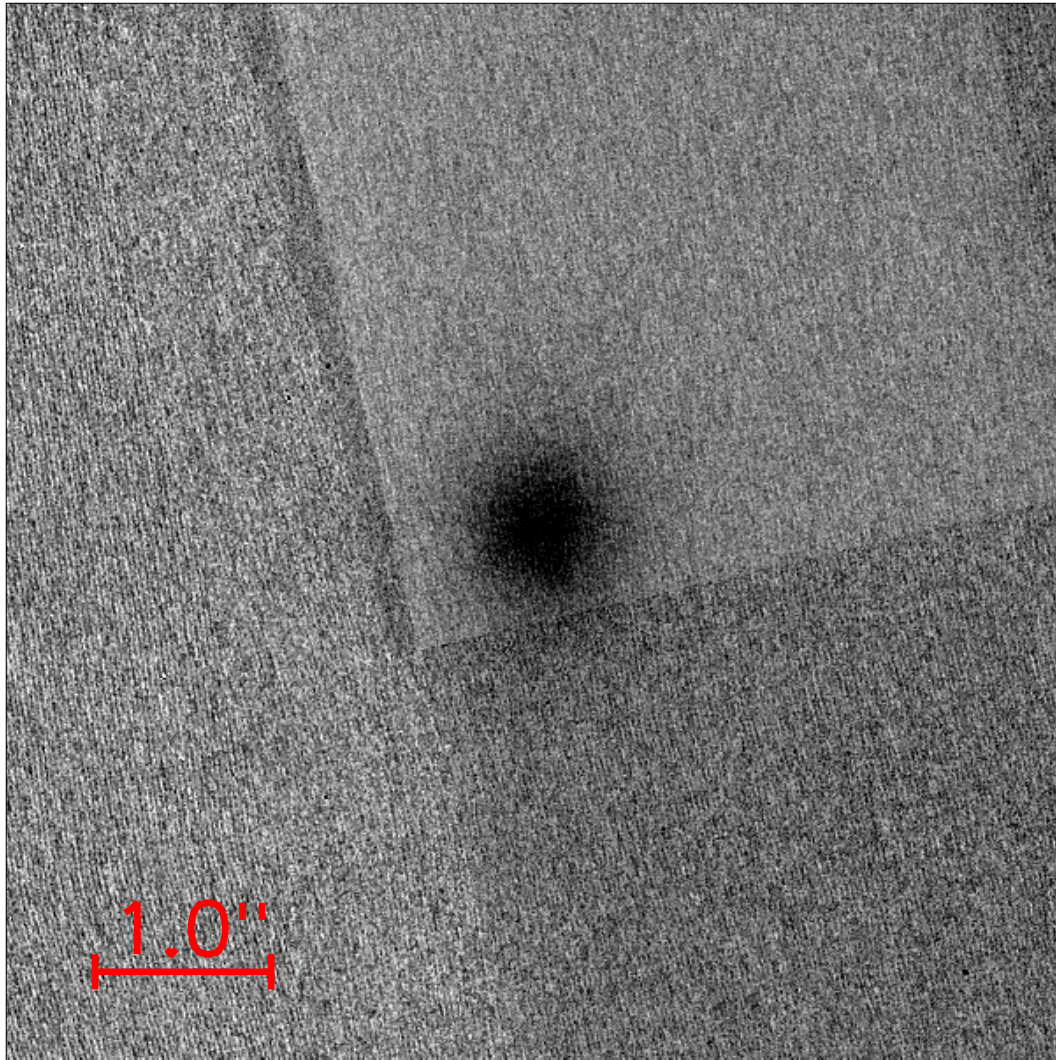


Figure 4. Seeing-limited image of V488 Per obtained with the Lp filter and NIRC2 camera on the Keck telescope on 31 March 2012 (UT). The pixel scale is 0.01". North is up, east to the left. The displayed image is a combination of three 20 second exposures (0.2 sec times 100 coadds per exposure). The images were obtained at an elevation of ~ 1.6 air masses just before the telescope hit a hard limit, so there was not time to well-center V488 Per. As a result, different noise levels are evident in various regions in the combined image which uses an inverted linear display. Since the infrared excess emission at V488 Per at this wavelength is about twice as bright as the photosphere, if the excess were coming from a somewhat offset background object then this image would look like a double star. The scalebar on the image indicates one arcsec; the WISE point spread function is about 6" FWHP at this wavelength. Data courtesy of C. Beichman, C. Gelino, G. Mace, J. Aycok, and R. Campbell.

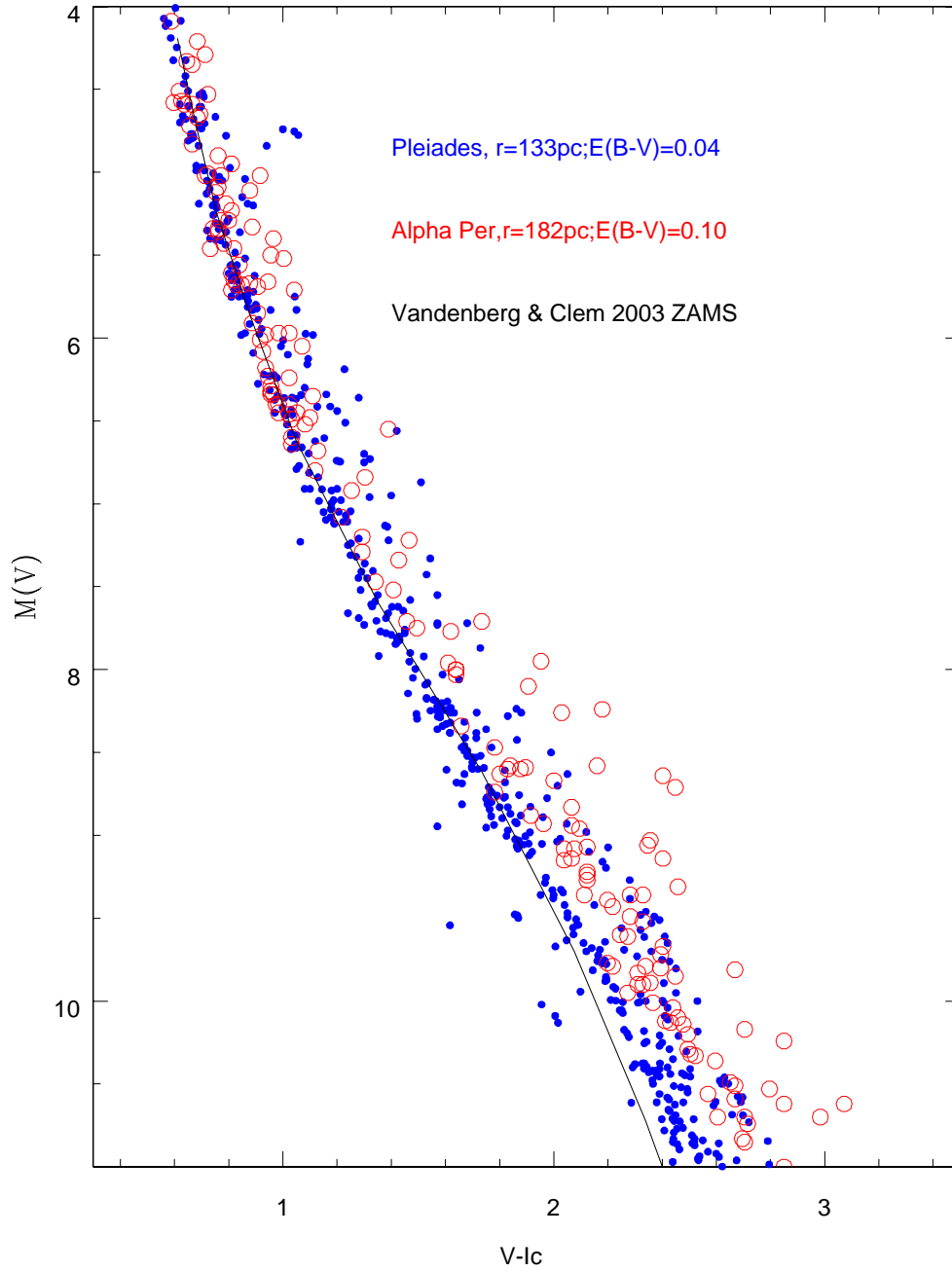


Figure 5. Comparison of color magnitude diagrams for the α Persei and Pleiades clusters (from B. Kamai et al 2012, in preparation). The figure has not been cleaned of multiple star systems. The data points for the Pleiades are from Stauffer et al (2007) and Kamai et al (2012, in preparation) and for α Per from Prosser (1992 and 1994) and Stauffer et al (1985 and 1989). The relative placement of the late-type stars shows that α Per is younger than the Pleiades.